Session 2: Joint Issues for Higgs, Electroweak, and Top

Overview

- What is covered in other sessions
- Higgs ⟷ Electroweak
- Top ⟷ Higgs

Rick Van Kooten
for the Higgs, EW, & Top groups
Indiana University

Snowmass Energy Frontier Workshop
3 – 6 April 2013
Brookhaven Naitonal Lab

Strawman Project List

From Community Planning Meeting at Fermilab

Synergies & Overlaps with other HEF Working Groups

- Electroweak:
  - vector boson scattering and unitarity recovery
    (dynamics of EWSB, composite Higgs?)
  - Precision indirect Higgs measurements vs. direct Higgs
- Top:
  - $t\bar{t}$ scan (g_{Htt} to ~30%)
  - $t\bar{t}H$ at different facilities, extract g_{Htt}
- New Particles:
  - Higgs decays into NP's, "weird/exotic" Higgs decays
  - Overlap with SUSY models and multiple Higgs
- Flavor & CP:
  - Flavor and CP-violating Higgs decays
- Simulations:
  - Common backgrounds

Higgs as a window into new physics

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Other sessions this meeting

Synergies & Overlaps with other HEF Working Groups

- Electroweak:
  - vector boson scattering and unitarity recovery
    (dynamics of EWSB, composite Higgs?)

    Thursday, Working Group Session 5:
    Vector Boson Couplings and VV Scattering
    (EW) (not specific for Higgs)

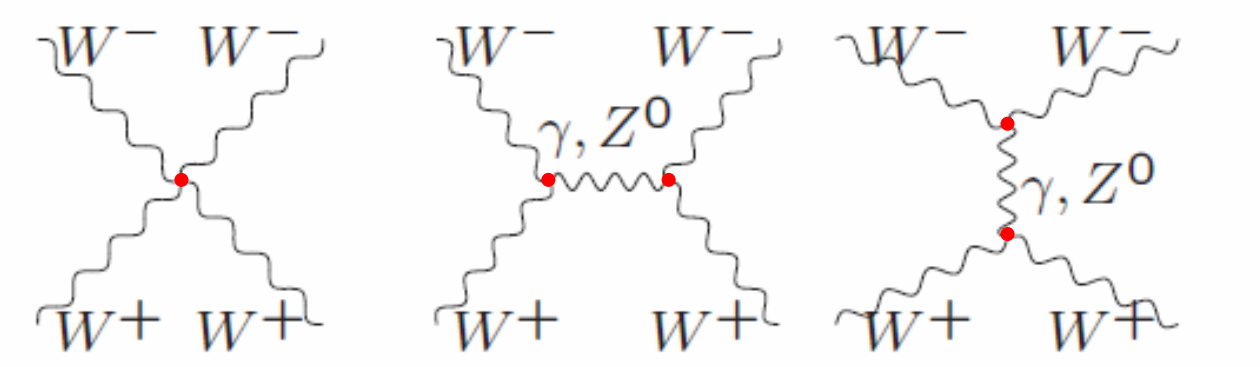
  - Precision indirect Higgs measurements vs. direct Higgs

    Friday, Working Group Session 6:
    Electroweak Precision Measurements and Implications
    (EW, Higgs, NP)

- Top:
  - $t\bar{t}$ scan (g_{Htt} to ~30%)
  - $t\bar{t}H$ at different facilities, extract g_{Htt}

Check high-energy behavior of the Higgs boson

Pure gauge coupling, longitudinally polarized *W*'s:

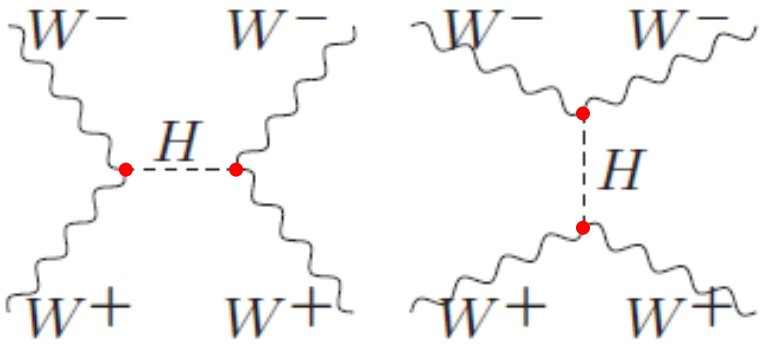


$\propto s^2$

$\rho = M_W^2/M_Z^2 \cos^2\theta_W$

$$\mathcal{M}_{\rm gauge} = -\frac{g^2}{4M_W^2}(4 - \frac{3}{\rho})u + \mathcal{O}(s^0)$$

...restore unitarity by adding scalar Higgs with *proper couplings*:

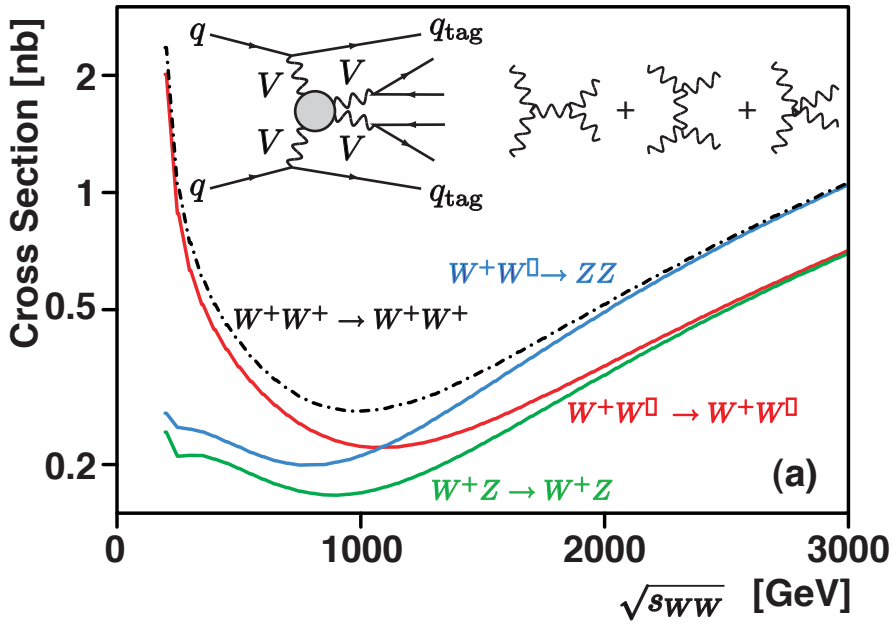


$$\mathcal{M}_H = \frac{g^2}{4M_W^2} + \mathcal{O}(s^0)$$

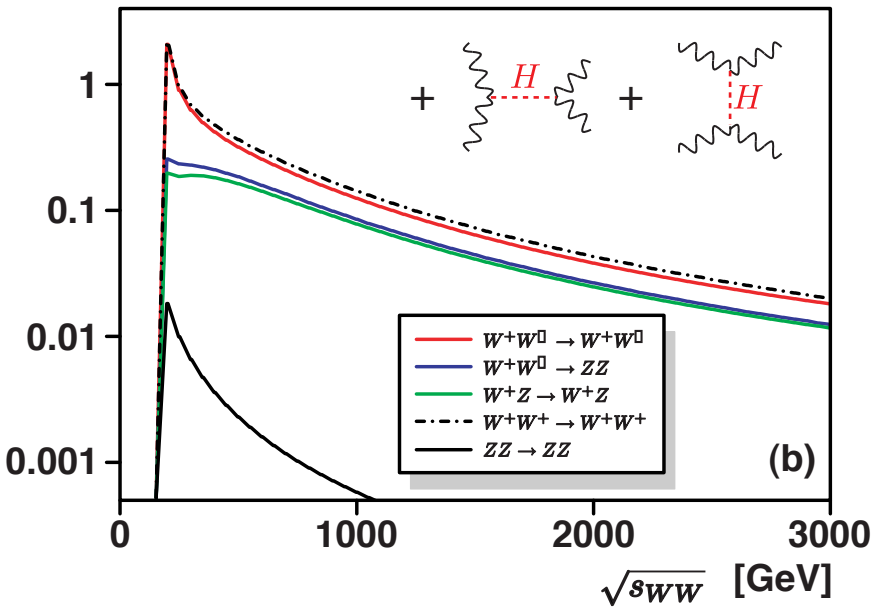
arXiv:0806.4145

Unitarity of the *WW* scattering can be restored by *(in addition to the observed 125 GeV boson)* composite Higgs, multi-Higgs, other strong resonances, etc.

No Higgs: increases, violates unitarity



With Higgs: unitarized



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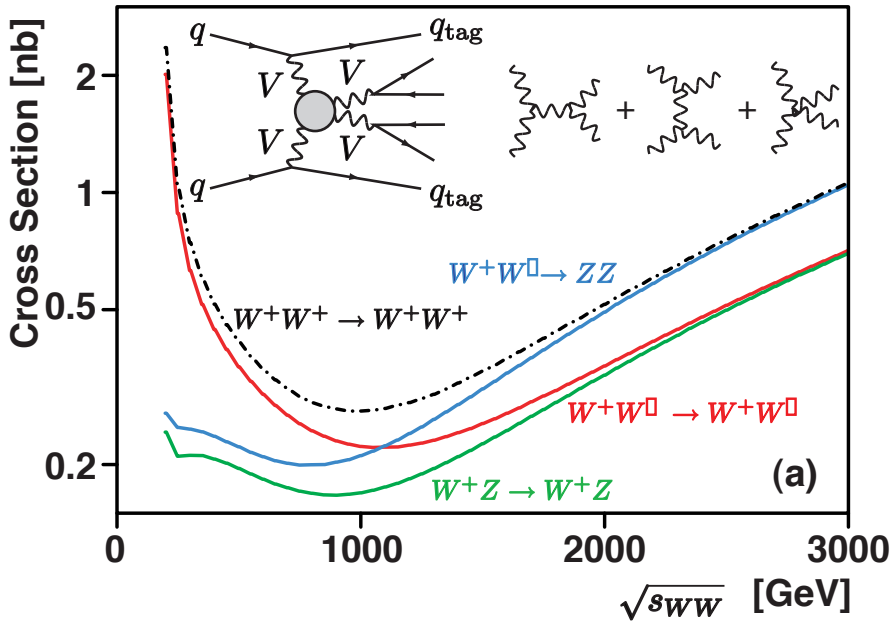

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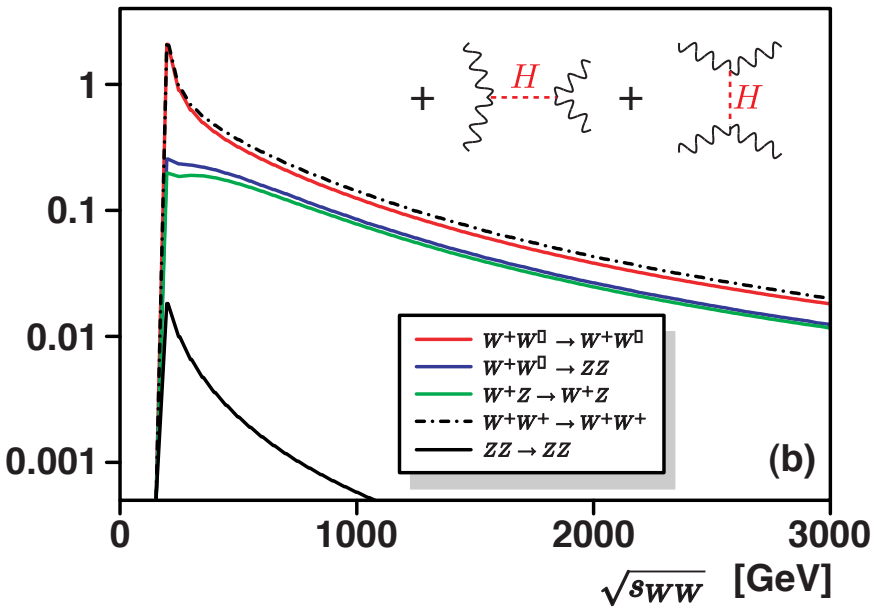
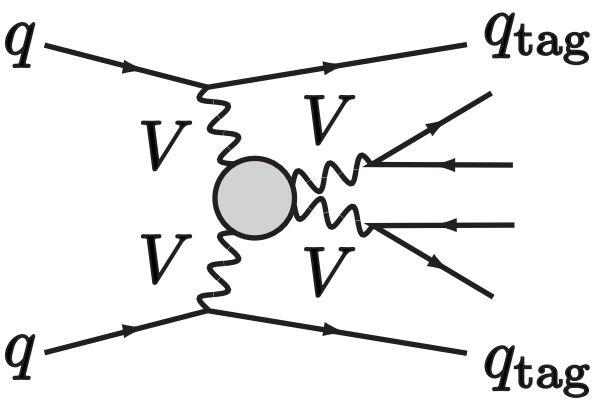


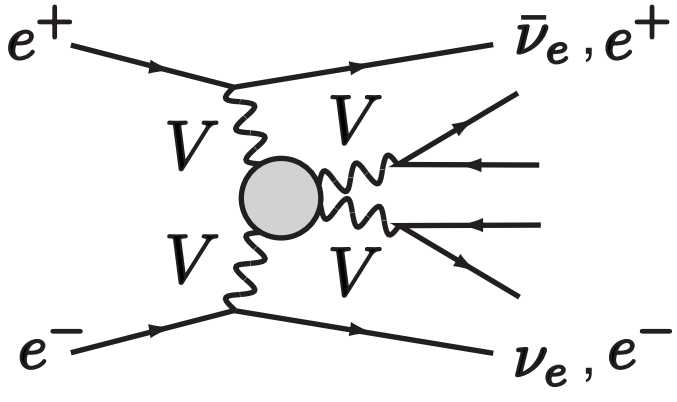
Unitarity of the *WW* scattering can be restored by *(in addition to the observed 125 GeV boson)* composite Higgs, multi-Higgs, other strong resonances, etc.

Most previous studies did not include, since usually invoked if a Higgs was *not* observed...

$\gtrsim$ 13 – 14 TeV



$\gtrsim$ 0.8 – 1 TeV



Forward Jets

- Higher the energy, the better
- Hadron colliders & lepton colliders
- Difficult analyses! Irreducible QCD & EW processes not taking part in the cancellation

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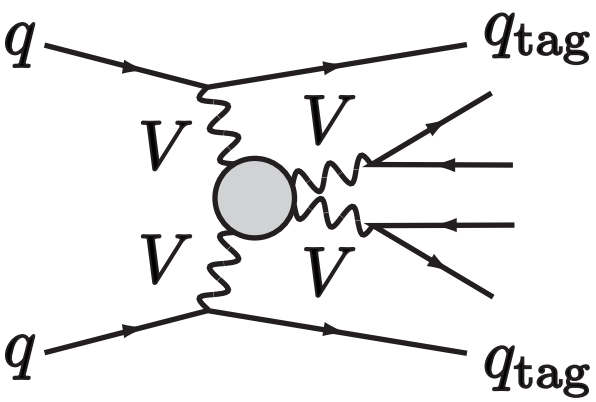

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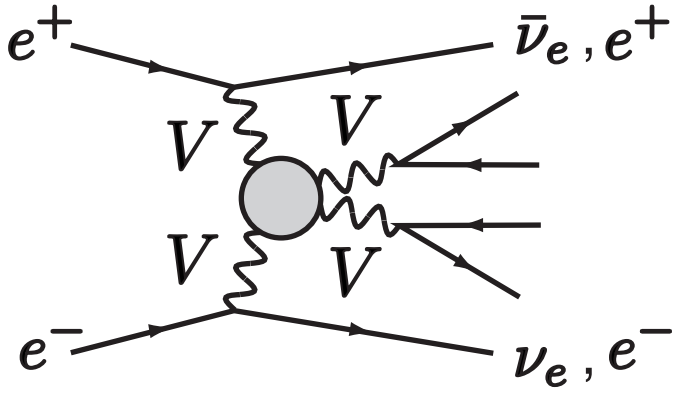

Forward Jets

- What complementary info do we learn in addition to other Higgs property studies?
- Best way to compare/complement "sensitivity" across facilities?
  - SM check of 125 GeV scalar
  - 125 GeV state is part of the new physics (multi-Higgs, etc.)
- Compare deviations from SM with the reach from other precision Higgs coupling measurements.
- What effects would only show up here?

Top Quark & Higgs

Top quark special?

$$g_{ttH} = \frac{m_t}{v} \qquad v^2 = \frac{1}{\sqrt{2} G_F}$$

$$\lambda_t = y_t = \sqrt{2} g_{ttH}$$

- modulo top pole mass issues, running of λ_t , using March 2013 Tevatron mass average:

$$\lambda_t = 0.995 \pm 0.005$$

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- Compare g_{ttH} precision across facilities (see later Higgs sessions for on couplings)

  Extracted from $t\bar{t}H$ production, $t\bar{t}$ threshold scan

- Including projected knowledge from LHC

  e.g., $t\bar{t}H$ from LHC, precision measurements of $\mathcal{B}(H \to b\bar{b})$ $\mathcal{B}(H \to W^+W^-)$

Desch et al., arXiv:0407159

- **Q:** although we always to be as model independent as possible, what will be precision on g_{ttH} from loop decay measurements?

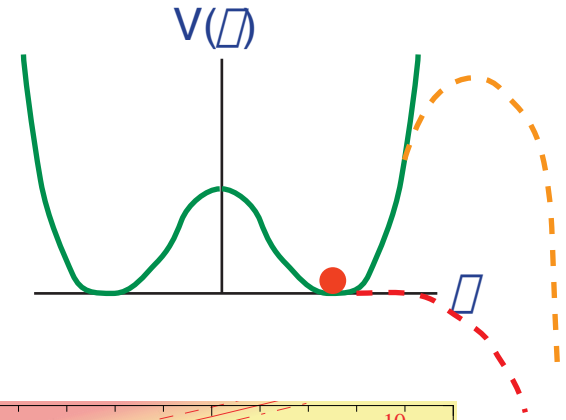
Top Quark & Higgs

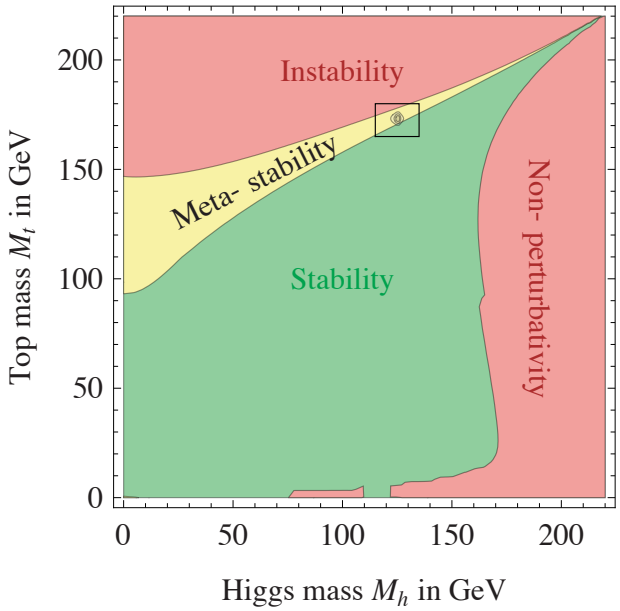
Snowmass: urged to go after the big questions:

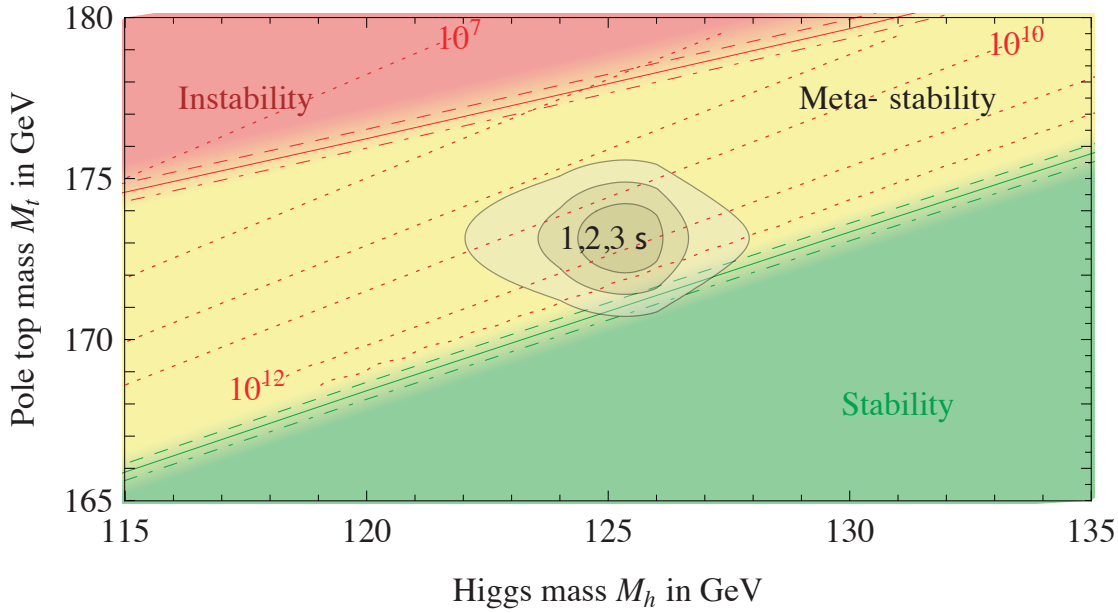
→ SM vacuum stability from M_t and M_H

(plus other improvements on other inputs)

→ (what if not SM?)







Strumia et al., arXiv:1205.6497

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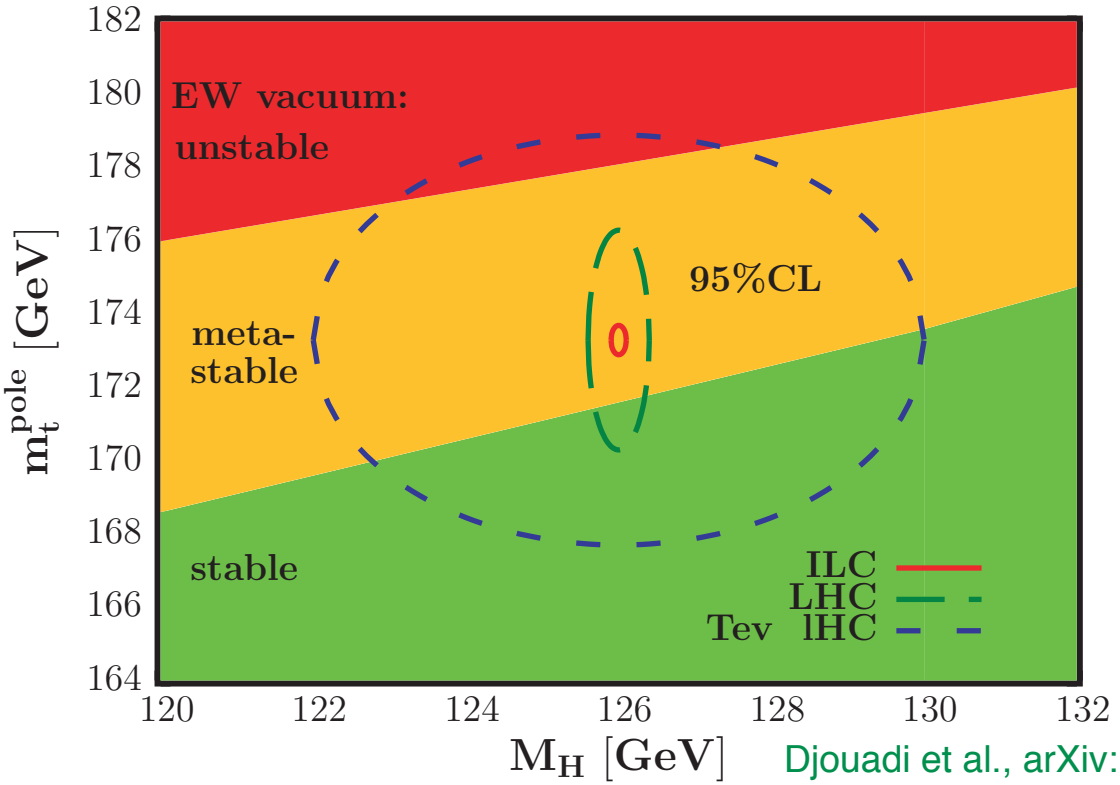

Djouadi et al., arXiv:1207.0980

- What other topics should be considered?